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NEUROSPORA EXPERIMENT P-1037

QUARTERLY PROGRESS REPORT

TO THE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

DECEMBER 16, 1966 - MARCH 15, 1967

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MAY 1968

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U. S. ATOMIC ENERGY COMMISSION

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Title of Project:

Mutagenic Effectiveness of Known Doses of Gamma Irradiation in Combination with Zero Gravity on Neurospora.

For the Period:

March 16 - June 30, 1967

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CONTENTS

I. INTRODUCTION

The present report for the period 16 March through 30 June 1967 discusses some of the problems encountered in the use of the passive dosimetry system which had been selected for inclusion in the Neurospora modules in the Biosatellite experiments and the development of procedures required to use these dosimeters with some assurance of accuracy.

Previous reports in this series are ORNL-TM-1734 (from inception of the project through 30 September, 1966), ORNL-TM-1959 (1 October through 15 December, 1966), and ORNL-TM-2189 (16 December, 1966 through 15 March, 1967). The first of these describes the design of the experiment, the development, qualification testing, and final form of the experimental hardware, early dosimetric procedures, storage and anoxia experiments, and biocompatibility testing. The second report, ORNL-TM-1959, discusses the assignment and field training of personnel for the Cape Kennedy and Hickam Field operations, additional biocompatibility tests, and the gantry exercises held immediately prior to the Biosatellite A flight. The third report, ORNL-TM-2189, deals mainly with the Biosatellite A flight, from which the flight material was not recovered, and presents the data from the ground control portion of the Biosatellite A experiment. Some of the data recording and electronic data processing techniques used for the Neurospora experiment are described and/or illustrated in that third report.

II. SELECTION OF CON-RAD THERMOLUMINESCENT DOSIMETRY (TLD) SYSTEM

Con-Rad (Controls for Radiation Inc., Cambridge, Mass.) disk dosimeters composed of lithium fluoride powder embedded in teflon and having a diameter of 13 mm and a thickness of 0.13 mm were chosen for inclusion in the Neurospora modules for measuring the gamma radiation exposures received by the conidia in the Biosatellite experiments. These were chosen for the following reasons: (1) they have approximately the same geometric shape as the layers of Neurospora conidia deposited on Millipore filters; (2) their dimensions are such that three can be inserted into each module disk immediately adjacent to the layers of conidia; (3) they are composed of essentially nontoxic material; (4) they can be oven-sterilized; (5) the disks were expected to be handled more easily than loose powder, which would require careful weighing and packaging; and (6) a Con-Rad thermoluminescent dosimetry read-out machine was already available in the division.

III. VARIATIONS IN SENSITIVITY OF DOSIMETERS

The disk dosimeters are described in the Con-Rad brochure entitled "An Introduction to the Con-Rad Thermoluminescence Dosimetry System" and numbered "Technical Information 14 (1-67)." Predictions concerning variability are presented in the following statement from page 4 of that brochure: "The 13 mm diameter LiF-Teflon Discs are normally used when relatively high sensitivity is desired. These discs are available in thicknesses of 0.13 mm, 0.26 mm, 0.4 mm, and 0.5 mm.

The 0.4 mm thick dosimeter is recommended for general use and has a range from 50 mR to 10^5 R, with precision of 3% S.D. over most of this range. The discs do not require individual calibration." Con-Rad representatives confirmed that these claims concerning variability and lack of requirement for individual precalibration applied to the 0.13 mm disks.

A large number of dosimeters from the same lot number (164144) were purchased and have been used during the gantry exercises and experiments related to the Biosatellite Project. As data accumulated, it became apparent that random samples of these dosimeters, if exposed to ionizing radiation identically, exhibited standard deviations in their thermoluminescence readings of as much as 14%, rather than 3% as claimed by the company. An early investigation of the effective life of the two batteries in the integrator-electrometer circuit showed that these often needed to be changed more frequently than the monthly intervals recommended by Con-Rad, but the variation in apparent dosimeter sensitivity was not attributable to this source.

IV. RELATIONSHIP BETWEEN DOSIMETER WEIGHT AND SENSITIVITY

The discovery that some of the dosimeters were less sensitive and visibly thinner than others suggested a source of variation. Individual weights of random sample of 250 dosimeters were determined and found to vary from 18.0 mg to 39.0 mg. The distribution of weights is indicated in Table 1 and Fig. 1. Of these dosimeters, 42 were taped to a sheet of plastic and irradiated identically (to 5000 R), and then plotted as to weight and thermoluminescence, as shown in Fig. 2.

There appears to be a general correlation between weight and sensitivity, but within a given weight class (e.g., 33 mg in Fig. 2) there is still considerable variation in sensitivity. To further illustrate this variation, a similar experiment was carried out with several dosimeters in each of five weight classes; the results are shown in Table 2 and Fig. 3. In the latter experiment, when dosimeters were removed from the sheet of plastic, some white powder, presumably lithium flouride, was found to adhere to the adhesive tape, and upon reweighing, some of the dosimeters had decreased in weight by as much as 1.0 mg.

To avoid this surface loss of lithium flouride, dosimeters representing particular weight classes were placed into glassine envelopes, which were in turn taped to the sheet of plastic and irradiated as before (to 5000 R). Reweighing showed that no change had occurred, but each weight class again exhibited a rather wide range of readings, as shown in Table 3 and Fig. 4. Standard deviations for weight classes varied from 3.4% for four dosimeters weighing 34.2 mg to 10.5% for nine dosimeters weighing 34.6 mg. The standard deviation for all 43 dosimeters was 8.68%. It appears that dosimeters vary both in weight and in lithium flouride content and/or distribution.

V. TESTS WITH MODIFIED PLANCHETS

A Con-Rad representative (Mr. Douglas Jones, Senior Physicist for the company), suggested that the type of planchet which we had used in previous tests was not interchangeable, and advised us to use a new type with a 7/16" diameter hole which exposes the dosimeter to the photodetector. In the older type of planchet the dosimeter is completely covered on the surface facing the photodetector with wire screening. Tests with the new open type of planchet were initiated.

Twelve dosimeters with a weight range of 31.5 to 33.5 mg were irradiated identically and subjected to thermoluminescence determinations with a single new open-style planchet. The readings (Table 4) had a standard deviation of 8.65%. In a second similar experiment, 41 dosimeters were tested for apparent sensitivity with four different new open-style planchets used for thermoluminescence determinations. The data (Table 5, Fig. 5) exhibited standard deviations of from 5.86% to 8.86% for dosimeters of identical weights. These results indicate that there remained an unexplained source of excessive variation not attributable to differences in planchets. Nevertheless, open planchets were used in all subsequent experiments.

VI. TESTS TO DETERMINE WHETHER THE READ-OUT MACHINE IS EXCESSIVELY VARIABLE

An attempt was next made to compare the variability of the thermoluminescence read-out machine at Oak Ridge with that of a similar machine at the Con-Rad facility. Forty-two dosimeters were classified by weights and exposed identically (to 5000 R of X-rays) in glassine envelopes. Half of these were read on the ORNL TLD read-out machine, and the other half were read on the machine at the Con-Rad facility at Cambridge, Mass. The same open-style, planchet was used for all readings. The variation in all ORNL readings combined (Table 6) was not different from the Con-Rad readings (about 11% standard deviation in both cases). Furthermore, when the readings were grouped by dosimeter weight (Table 7) and the standard deviations computed, these standard deviations ranged from 2.3% to 6.0% in the ORNL readings and from 3.3% to 8.1% for the Con-Rad readings. It was obvious that the variation in readings was attributable not to the particular TLD read-out machine or to the technique used at ORNL, but more probably to variation in sensitivity of individual dosimeters. It was suggested by Con-Rad personnel that the following difficulties in production of these dosimeters might contribute to the variation: (1) in the production of the lithium fluoride crystals, which are subsequently powdered, there are variations in radiosensitivity at different points in the crystal; (2) the uniform distribution of lithium fluoride powder through a cylindrical teflon matrix is not easily achieved; (3) the precision of the equipment used to slice 0.13 mm thick disks from the cylinder is such that variations (such as those described above) in thickness might occur.

VII. PROCEDURE FOR USING DOSIMETERS VARYING IN RADIOSENSITIVITY

Precalibration of individual dosimeters was decided upon as the only way of working with this dosimetric system. The technique recommended by a Con-Rad representative was developed by Bengt Martensson and is as follows: (1) irradiate all dosimeters to a given low dose of ionizing radiation; (2) make thermoluminescence determinations; (3) anneal dosimeters for 24 hours at 80°C; (4) divide the reading from each dosimeter by the average reading for all dosimeters to obtain a reading-correction factor; and (5) multiply the reading from an experimental exposure by the correction factor for the dosimeter used. The most restrictive requirement of this system is that the temperature exposures and cooling rates for all dosimeters be identical; this requirement was met by allowing each dosimeter to cool for no less than one minute in the TLD read-out machine after the completion of the reading cycle and by making necessary repeated checks and adjustments of the 80°C annealing oven.

To test this procedure, 44 dosimeters in selected weight ranges were exposed identically (to 500 R of X-rays) and subjected to TLD read-outs. Twenty-five dosimeters in the weight range 34.0 to 34.8 mg gave readings with a standard deviation of 6.42% and nineteen dosimeters in the range 31.0 to 31.8 mg gave readings with a standard deviation of 3.92%. Correction factors were determined by dividing by the average reading for all 44 dosimeters. The dosimeters were then annealed for 24 hours at 80°C, exposed identically (to 5000 R X-rays), and subjected to TLD determinations. These readings were multiplied by the appropriate correction factors, and the corrected readings from the 31.0 to 31.8 mg group had a standard deviation of 3.12%, while those from the 34.0 to 34.8 mg group had a standard deviation of 2.16%. The individual corrected readings are shown in Fig. 6; it appears that no additional correction factor for weight difference need be applied.

Although this correction procedure involves a considerably greater expenditure of time and effort than had been anticipated, it appears to give satisfactory results (with a precision of about 3% standard deviation) and has been adopted for use with Con-Rad dosimeters in the Biosatellite Project. During these investigations and, in part, because of the difficulties encountered with the Con-Rad system, an additional passive dosimetry system was adopted which was thought to be more reliable and which had, in fact, provided some additional information about radiation quality. The additional system will be discussed and compared with the Con-Rad system in a subsequent report.

VIII. SUMMARY

It was discovered that the variability in sensitivity to ionizing radiation obtained with Con-Rad disk dosimeters of 13 mm diameter and 0.13 mm thickness was greater than the manufacturer's predictions, and that there was also considerable variation in weight of dosimeters. Investigations concerning the cause of the sensitivity variation suggested a number of ways of obtaining increased accuracy. (1) The batteries in the read-out machine must be replaced at monthly intervals and sometimes some frequently. (2) Adhesive tape may not be applied directly to the dosimeters as this causes loss of lithium fluoride particles from the surface; the dosimeters should first be wrapped in paper or enclosed in glassine envelopes before being taped to a surface. (3) A new type of planchet was adopted on the recommendation of the manufacturer. (4) Precalibration of dosimeters and use of individual correction factors for the readings from each dosimeter were adopted as mandatory.

Table 1

Distribution of weights of a random sample of 250 Con-Rad lot No. 164144 Lif-Teflon TLD disk dosimeters to the nearest 0.1 mg.

Mg.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
18		1								
19									1	
21						1				
22				1						
23				1						
24									1	
25	1								1	
26					1					
27	1	1					1			1
28			1							
29	1						1	1		
30	1		1		2		5			
31	5	2			1	3	5	5	9	5
32	7	6	7	4	1	3	4	5	6	
33	7	7	7	2	7	4	5	20	4	5
34	17	4	4	5	7	5	9	3	5	2
35	4	3		1	2	1				
36			1			1	1			
37	1					1				
39									1	

Table 2

Weights of lot No. 164144 dosimeters before and after direct contact with adhesive tape.

	Mg. weight before contact	Mg. weight after contact	Mg. difference
1.	33.7	32.9	0.8
2.	33.7	33.0	0.7
3.	33.7	33.0	0.7
4.	33.7	33.2	0.5
5.	33.7	33.1	0.6
6.	33.7	33.2	0.5
7.	33.7	33.2	0.5
8.	33.7	33.1	0.6
9.	33.7	33.0	0.7
10.	33.7	33.4	0.3
11.	33.7	32.9	0.8
12.	33.7	33.0	0.7
13.	33.7	33.1	0.6
14.	33.7	33.2	0.5
15.	33.7	33.3	0.4
16.	33.7	33.4	0.3
17.	32.0	31.6	0.4
18.	32.0	31.7	0.3
19.	32.0	31.6	0.4
20.	32.0	31.8	0.2
21.	32.0	31.7	0.3
22.	32.0	31.7	0.3
23.	33.1	32.7	0.4
24.	33.1	32.8	0.3
25.	33.1	32.6	0.5
26.	33.1	32.6	0.5
27.	33.1	32.7	0.4
28.	33.1	32.6	0.5
29.	33.1	32.6	0.5
30.	34.0	33.4	0.6
31.	34.0	33.2	0.8
32.	34.0	33.0	1.0
33.	34.0	33.4	0.6
34.	34.0	33.3	0.7
35.	34.0	33.3	0.7
36.	34.0	33.2	0.8
37.	34.0	33.4	0.6
38.	34.0	33.4	0.6
39.	34.0	33.4	0.6
40.	34.5	34.1	0.4
41.	34.5	34.1	0.4
42.	34.5	33.7	0.8
43.	34.5	33.9	0.7
44.	34.5	34.0	0.5

Table 3

Distribution of readings at preselected weights of lot No. 164144 dosimeters identically irradiated.

Weight	Low read	High read	Avg. read	% SD	No. readings
31.6-35.1	963	1418	1172	8.68	43
32.2	972	1266	1166	9.38	6
32.6	1026	1258	1126	9.07	5
33.2	1042	1204	1138	4.73	7
33.6	1094	1366	1186	9.35	5
34.2	1187	1266	1228	3.4	4
34.6	963	1418	1219	10.5	9

Table 4

Thermoluminescence readings (arbitrary units) of identically irradiated lot No. 164144 dosimeters obtained with a single new open style planchet with a 7/16" diameter hole cut in the screen.

Weight	Reading
33.5	3946
33.5	4300
33.0	3550
33.0	3850
32.9	3576
32.9	4316
32.9	3940
32.0	4222
32.0	3684
31.5	3468
31.5	3318
31.5	3718

Table 5

Comparison of reading of identically irradiated lot No. 164144 dosimeters with several of the new open style planchets.

	Planchet number	Reading	Weight	% SD
1.	1	2500		
2.	1	2094		
3.	2	2450		
4.	2	2342		
5.	3	2162	31.8	7.2
6.	3	2386		
7.	4	2334		
8.	4	2065		
9.	1	2520		
10.	1	2364		
11.	2	2402		
12.	2	2800	34.4	5.86
13.	3	2474		
14.	3	2420		
15.	3	2442		
16.	1	2643		
17.	1	2644		
18.	2	2250		
19.	2	2424	33.4	6.27
20.	3	2344		
21.	3	2635		
22.	4	2494		
23.	4	2278		
24.	4	2317		
25.	4	2447		
26.	1	2220	32.8	7.62
27.	1	2624		
28.	2	2444		
29.	2	2122		
30.	3	3278		
31.	3	1922		
32.	4	2225	22.1	8.86
33.	4	1896		
34.	4	2244		
35.	1	2420		
36.	1	1952		
37.	2	2350	32.7	8.10
38.	2	2324		
39.	2	2324		
40.	3	2047	35.4	
41.	3	2035		

Table 6

Comparison of readings at ORNL and at Con-Rad facility of lot No. 164144 dosimeters irradiated identically at ORNL with 5000 R X-rays.

Weight	ORNL	Cambridge
23.0	1438	
28.2	1943	348
30.6	2043	347
	2138	394
31.0	2222	389
	2236	430
31.9	2338	492
		440
32.3	2137	418
	2192	462
33.0	2330	405
	2392	446
33.5	2420	405
	2308	445
33.9	2442	384
	2328	475
34.3	2402	471
	2252	492
34.9	2568	509
	2344	500
35.6	2466	476
% Range	50.3	37.15
Standard Deviation	10.78	11.23

Table 7

Percentage standard deviations of readings obtained with ORNL reader and Con-Rad reader at Cambridge in lot No. 164144 dosimeters irradiated at ORNL with 5000 R X-rays.

Weight range	ORNL	Cambridge
23.0 - 35.6	10.78	
28.2 - 35.6		11.23
31.0 - 32.3	3.31	8.12
33.0 - 33.9	2.33	7.97
34.3 - 35.6	5.97	3.25
33.0 - 35.6	3.65	9.22

ORNL-BIO-18909

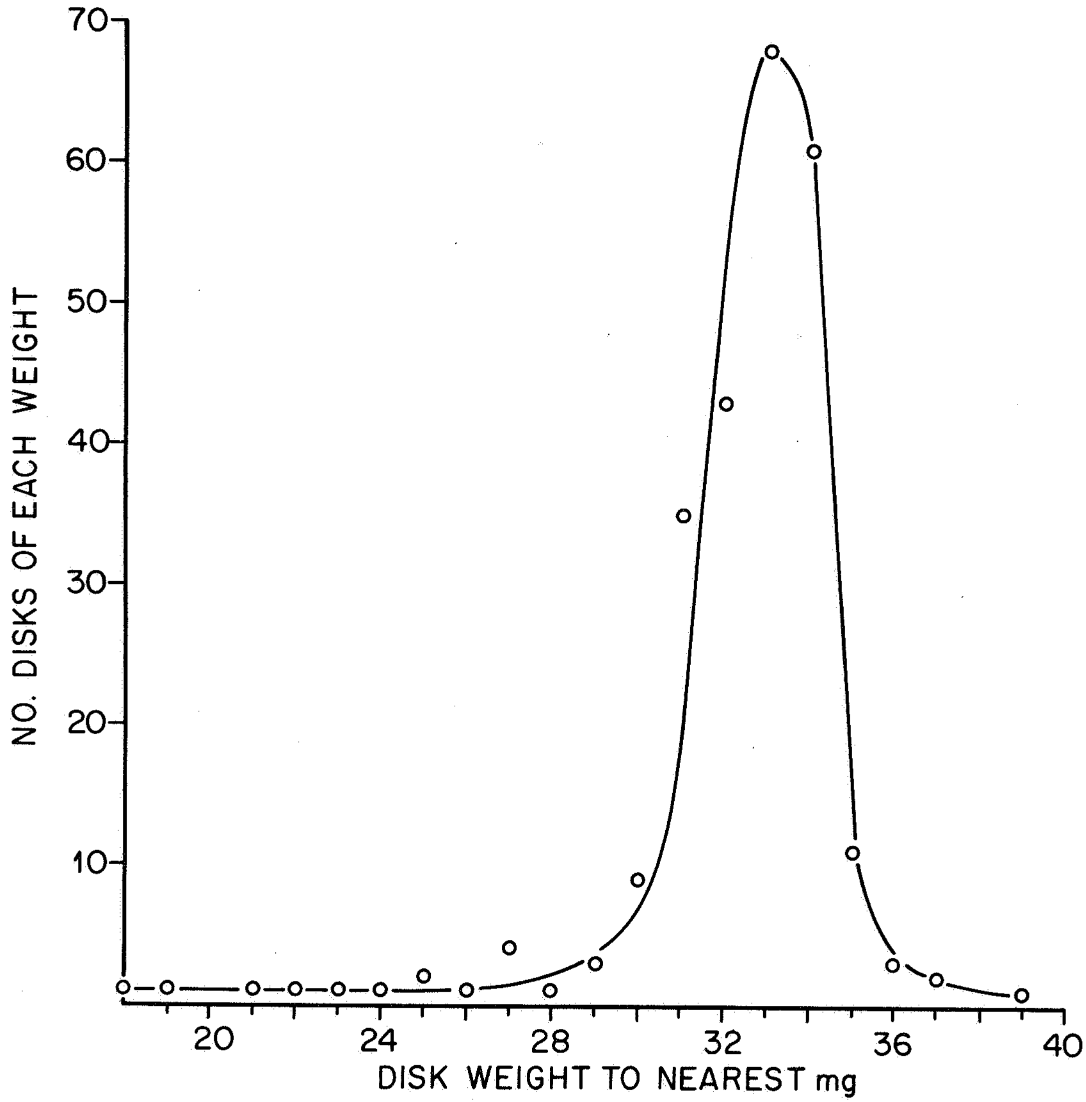

Figure 1. Weight distribution of a random sample of Con-Rad lot No. 164144 LiF-teflon TLD disk dosimeters.

ORNL-BIO-18910

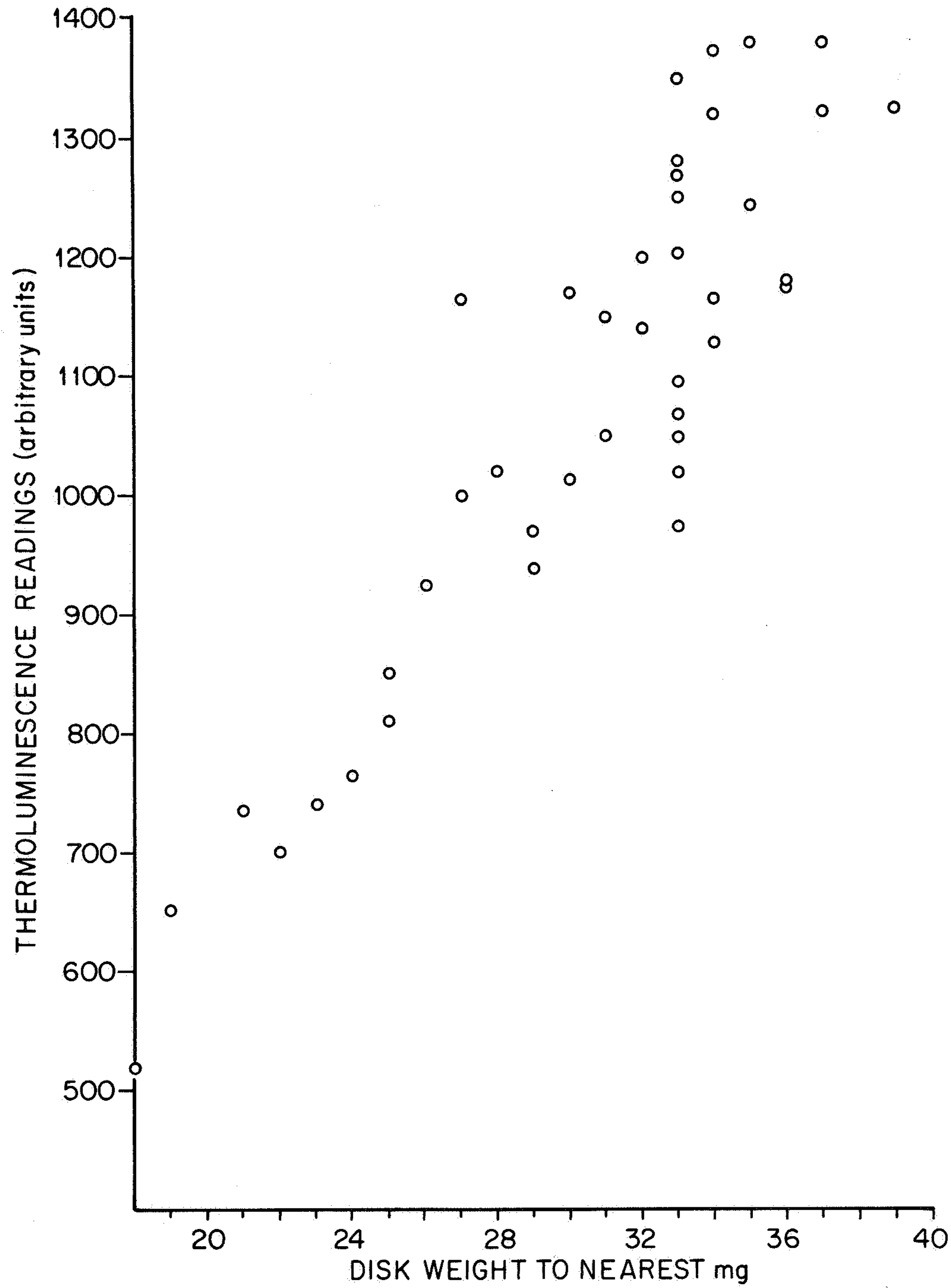

Figure 2. Distribution of disk weights and radiation sensitivities in lot No. 164144 dosimeters.

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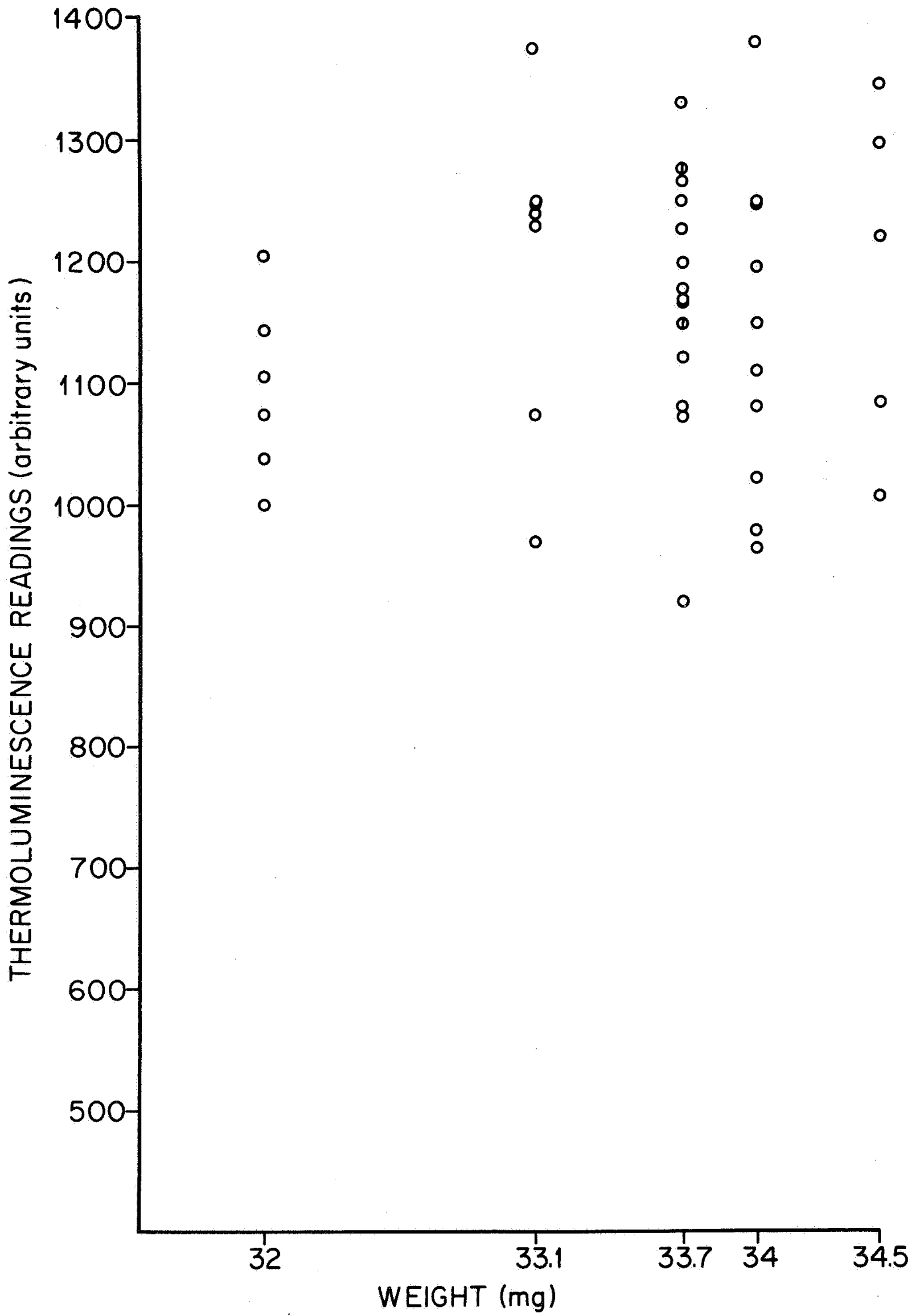

Figure 3. Distribution of preselected weights and TLD readings with identically irradiated lot No. 164144 dosimeters after direct contact with adhesive tape.

ORNL-BIO-18912

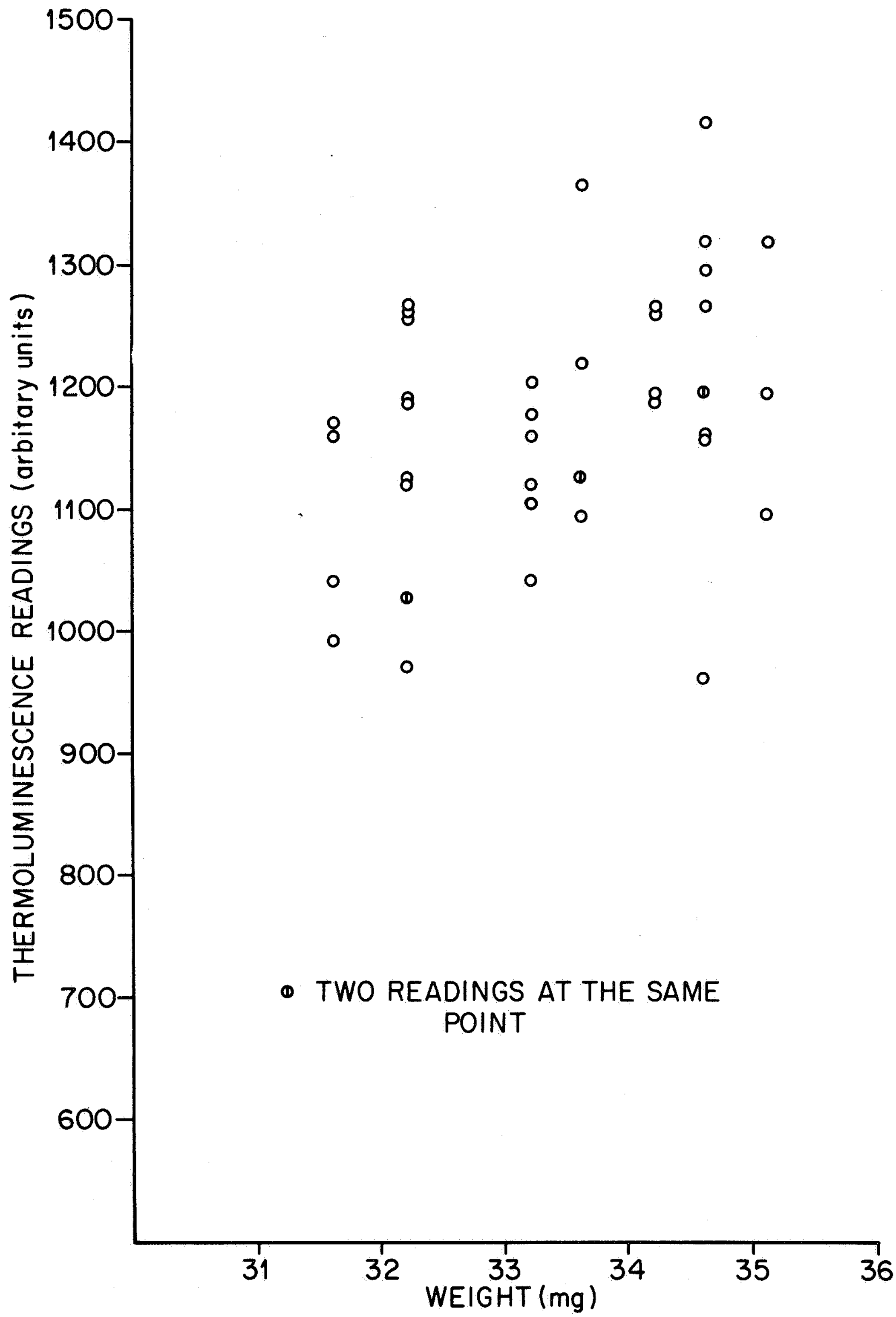

Figure 4. Distribution of TLD readings and selected weights of lot No. 164144 dosimeters identically irradiated without contact with adhesive tape (in glassine envelopes).

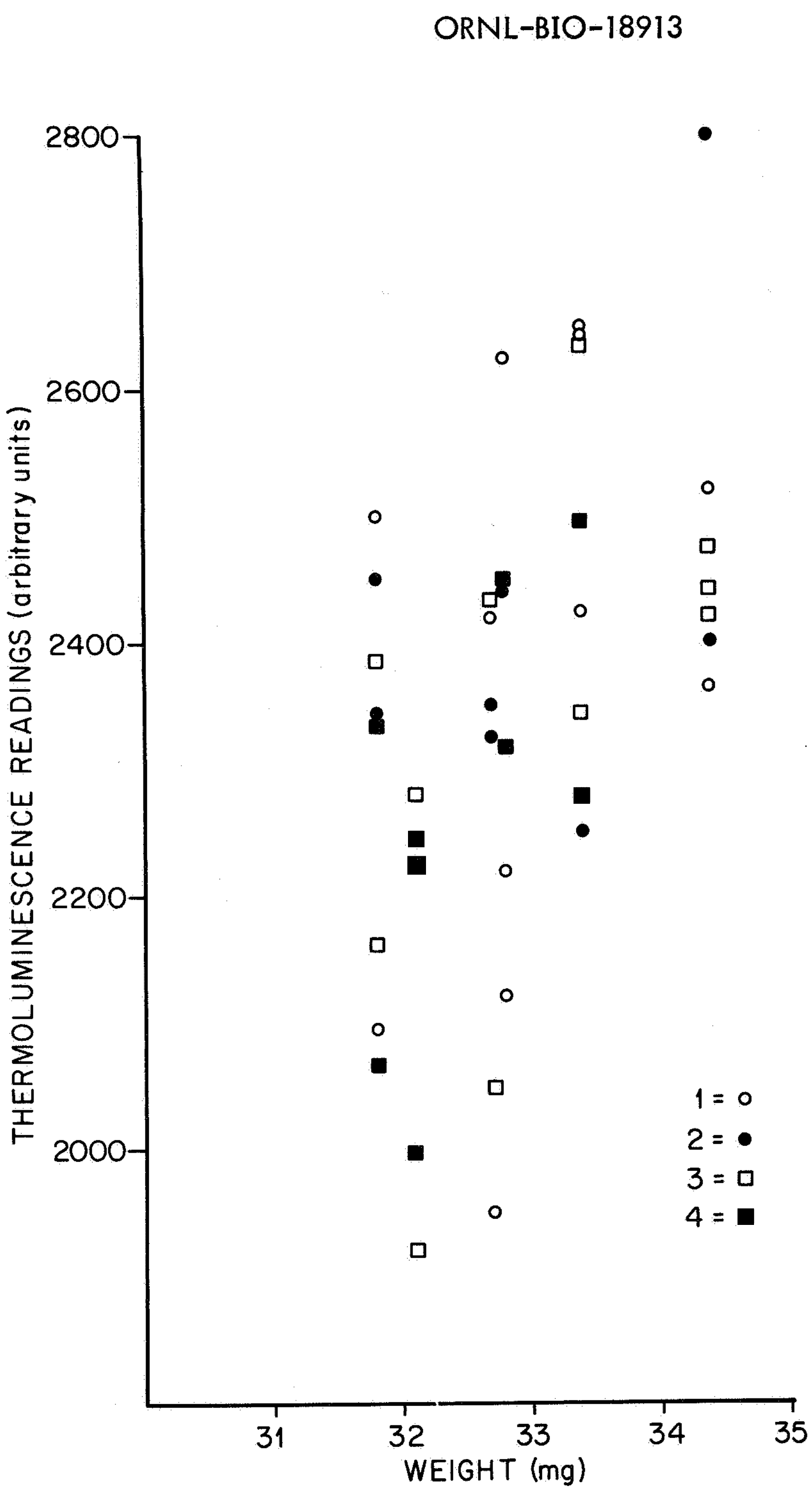

Figure 5. Distribution for lot No. 164144 dosimeters of TLD readings obtained with new planchets with 7/16-inch diameter hole cut in screen.

ORNL-BIO-18914

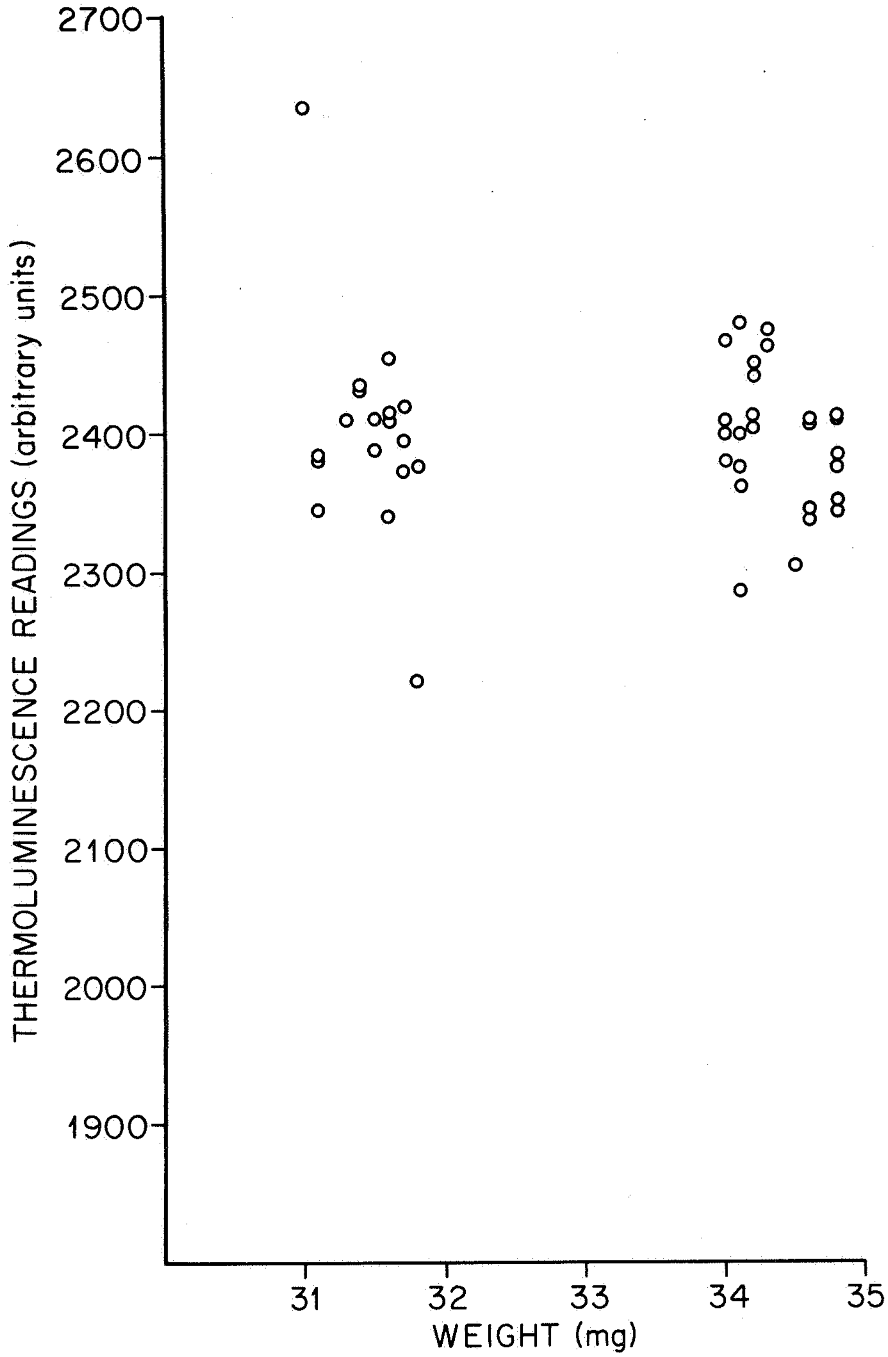

Figure 6. Weights and corrected TLD readings of lot 164144 dosimeters after exposure to 5000 R. Corrections are based on pre-calibration of each dosimeter.

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